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Development of Simple Screening Criteria for the Indoor Air Exposure Pathway

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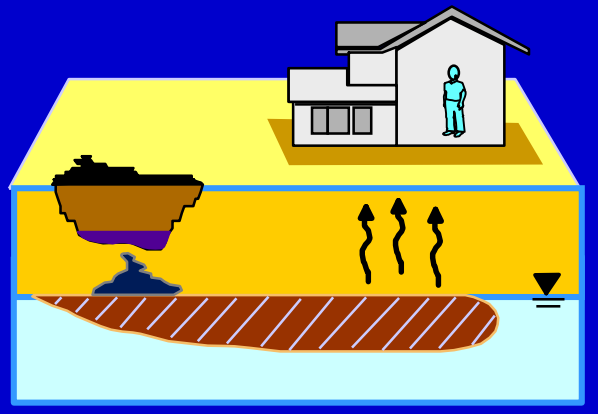
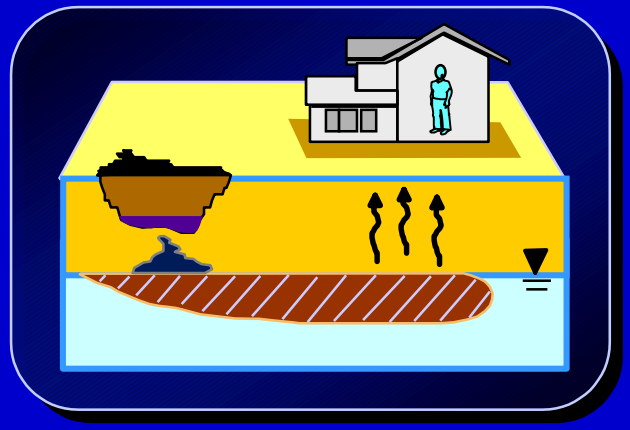


Screening Criteria for Indoor Air Pathway

- Objectives / Approach
- Site Database: *Evaluation of J-E Model*
- Site Database: *Screening Criteria*
- Recommended Screening Approach



Screening Criteria for Indoor Air Pathway

Project Objectives: *What We Did*

1 ***Johnson-Ettinger Model:***

Evaluate utility as screening-level model.

2 ***Empirical Screening Criteria:***

Develop simple rules re: absence of indoor vapor exposure risk for fuels and solvents.

Rule of Thumb

vs.

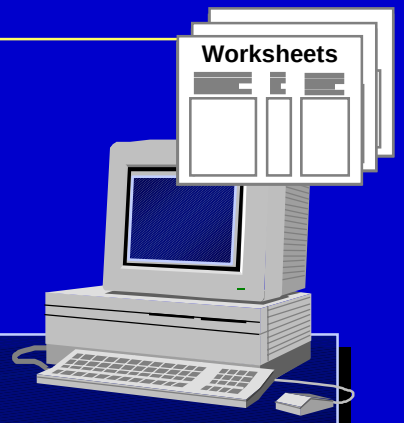
Model

GOAL: **Using actual site measurements, develop simple screening guidelines for evaluation of indoor air exposure pathway for organic compounds.**

Screening Criteria for Indoor Air Pathway

Site Database: *Description*

Sources	■ Massachusetts DEP (83 cases) and other published studies (10 cases).
Data Types	■ Actual COC conc. measurements in GW (85), soil vapor (8), indoor air (93), and background air. ■ Other site info: Soil type, DTW, foundation type, NAPL
Data Population	■ 31 Locations: MA (27), CA (2), NJ (1), Canada (1) ■ 93 cases: Individual COC measurements at any site.



KEY POINT: Database is **NOT** a random sampling. Results biased high as only problem sites were measured and most MA measurements conducted in winter*.

DTW = Depth to water; NAPL = Non-aqueous phase liquid

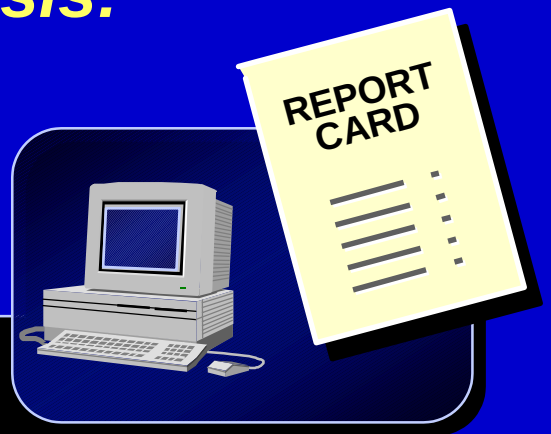
* Conducted between December and March

Screening Criteria for Indoor Air Pathway

Johnson-Ettinger Model: *Performance Evaluation*

Evaluate on Two Levels

- ***Quantitative Analysis:***
  Reliable prediction of indoor vapor concentration?
- ***Screening Level Analysis:***
  Reliable prediction of indoor vapor RBEL exceedance or non-exceedance?



KEY APPROACH:

Use site-specific inputs for L_s, COC, and C_s to get best indoor vapor estimate, not conservative high estimate.

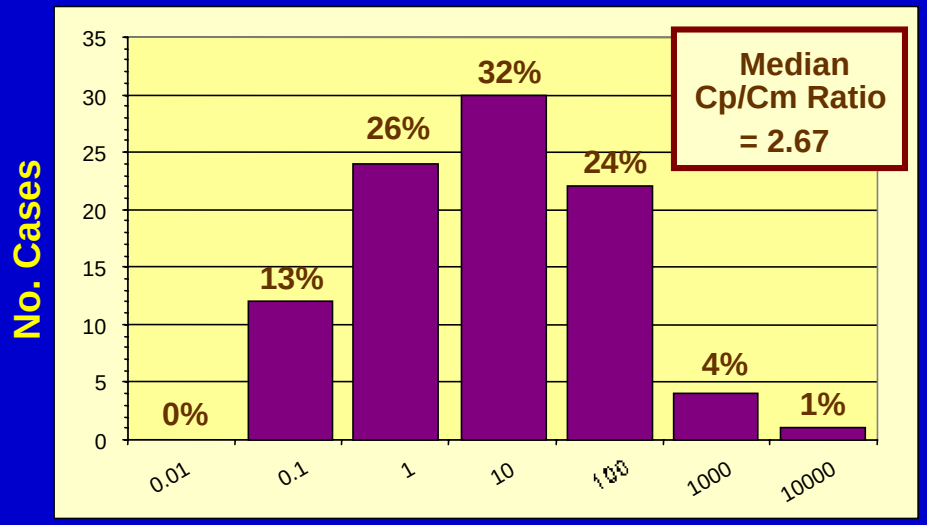
RBEL = Risk-Based Exposure Limit; COC = Constituent of Concern; Ls = Depth to source; Cs = Source concentration

Screening Criteria for Indoor Air Pathway

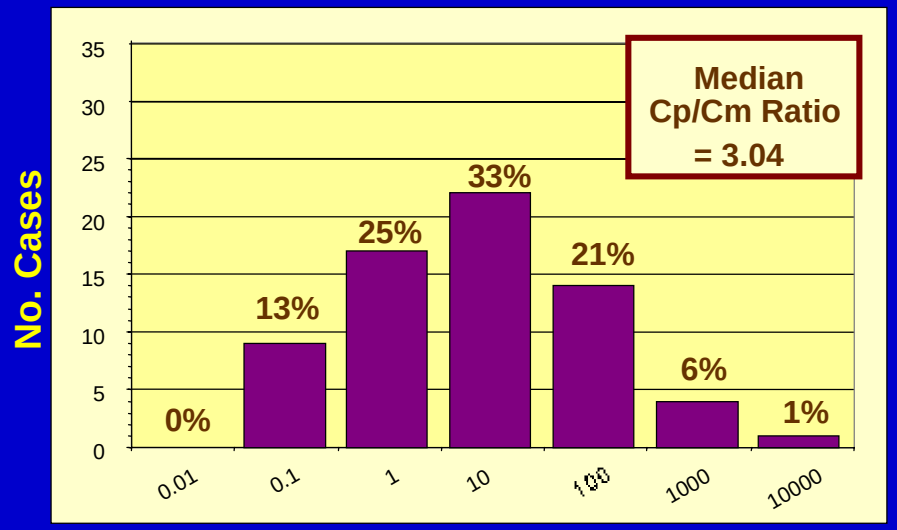
J-E Model: Evaluation of Bias C_p vs. C_m

Diffusion-Only Mode: Distribution of C_p/C_m Ratio

All COCs



Fuels



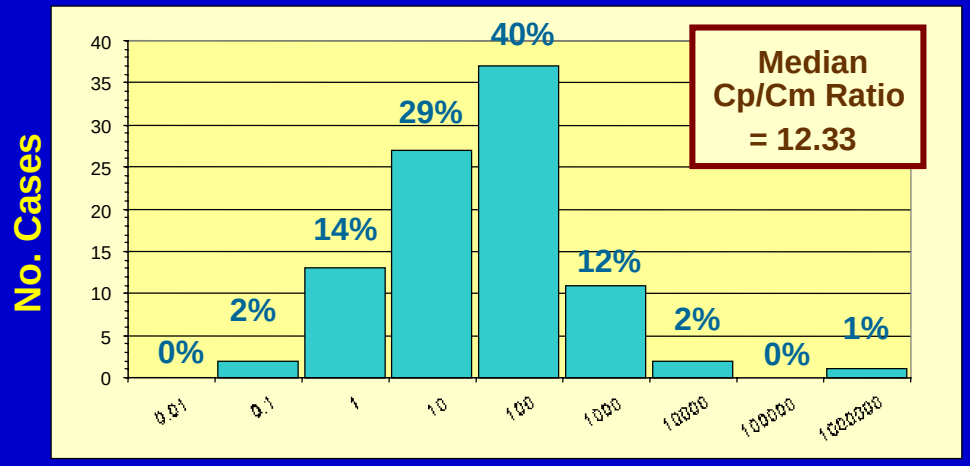
KEY POINT: Diffusion-only mode shows poor accuracy (10x error 41 % of time for all COCs) but only moderate bias (overpredicts actual concentration 61 % of the time with median C_p/C_m ratio of 2.7 for all COCs, 3 for fuels).

Screening Criteria for Indoor Air Pathway

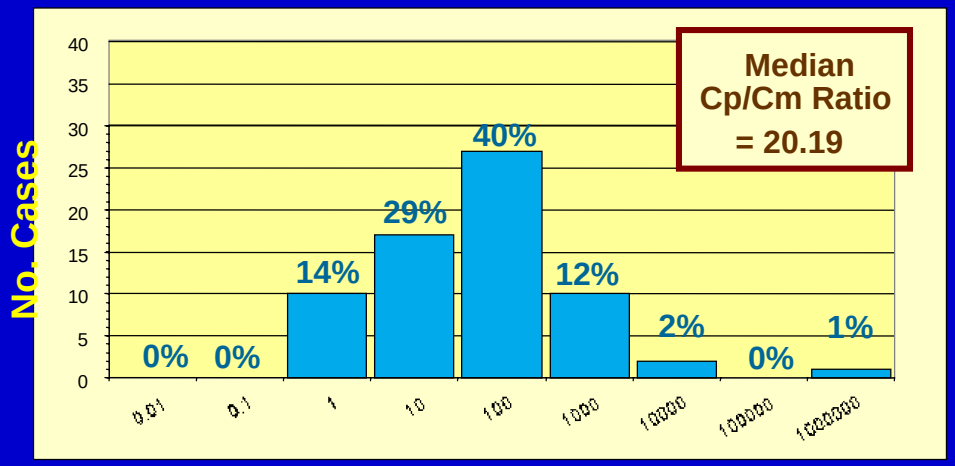
J-E Model: Evaluation of Bias C_p vs. C_m

Diffusion / Advection Mode: Distribution of C_p/C_m Ratio

All COCs



Fuels



KEY POINT: Diffusion-Advection mode has poor accuracy (>10 x error 57 % of time) and high bias (overpredicts actual concentration 84 % of time with median C_p/C_m ratio of 12 for all COCs, 20 for fuel COCs).

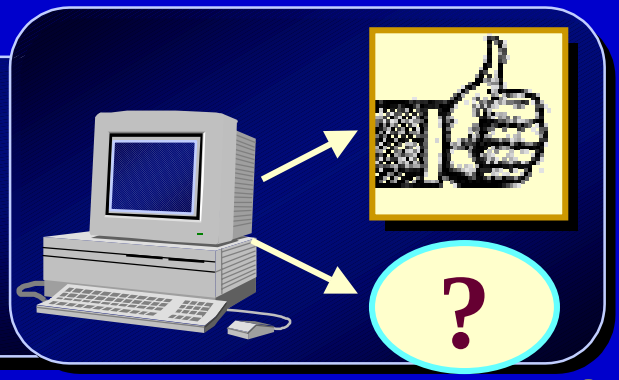
Screening Criteria for Indoor Air Pathway

J-E Model: Screening-Level Analysis (C_p vs. RBEL)

Performance Criteria for Screening Model

- ***Vapor Exposure Level:***
  Correctly identifies C_m < RBEL or > RBEL?
- ***False Positive:***
  Says C_m > RBEL or > Backgrd when not
- ***False Negative:***
  Says C_m < RBEL or < Background when not

GOAL: **Useful screening-level model should have no false negative, minimal false positive results re: RBEL exceedance.**



Cp = Predicted concentration in indoor air; Cm = Measured indoor air vapor conc. RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

Risk-Based Exposure Limits (RBELs) for Residential Inhalation Exposure

CHEMICALS OF CONCERN		Carcinogenic Inh. RBEL (10^{-6}) (mg/m^3)	Carcinogenic Inh. RBEL (10^{-5}) (mg/m^3)	Noncarcinogenic Inh. RBEL (HQ =1) (mg/m^3)
Solvent COCs	1,1,1-Trichloroethane	N/A	N/A	**1.00E+00**
	1,1-Dichloroethene	**4.90E-05**	**4.90E-04**	N/A
	Tetrachloroethene (PCE)	**4.20E-03**	**4.20E-02**	2.80E-01
	Trichloroethene (TCE)	**1.40E-03**	**1.40E-02**	N/A
	cis-1,2-Dichloroethene	N/A	N/A	**8.30E-01**
Fuel COCs	Benzene	**3.10E-04**	**3.10E-03**	6.30E-03
	Ethylbenzene	N/A	N/A	**1.00E+00**
	Toluene	N/A	N/A	**4.20E-01**
	Xylene, Total	N/A	N/A	**4.50E-01**
	Metyl tert-Butyl Ether (MTBE)*	**5.40E-02**	**5.40E-01**	3.10E+00

NOTES:

1) * MTBE RBEL at a target risk of 10^{-5} obtained from Texas Risk Reduction Program Tier 1 Tables, 30 TAC 350.
2) Values used in evaluating data are shown in **bold.**
3) RBEL = Risk-Based Exposure Limit.

Screening Criteria for Indoor Air Pathway

J-E Model: Screening-Level Analysis (C_p vs. RBEL)

Performance Criterion	No. Cases	Diffusion Only (Qs = 0) All COCs	No. Cases	Diffusion /Advection (Qs > 0) All COCs
RBEL Exceedance (10^{-6})				
■ False Positive	14	15 %	27	29%
■ False Negative	5	5 %	2	2 %
RBEL Exceedance (10^{-5})				
■ False Positive	16	17%	30	32%
■ False Negative	3	3 %	1	1%

KEY FINDING: **Model predictions provide significant false positive results, particularly for diffusion/advection mode.**

Cp = Predicted concentration in indoor air; RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

J-E Model: Summary Findings

J-E Model

- ***As Screening Level Tool:***

  1) <u>Diffusion-Only Mode</u>:
  Poor accuracy, low-bias model may overpredict or underpredict actual indoor vapor level.

  2) <u>Diffusion-Advection Mode</u>:
  Poor accuracy, high-bias model provides high false positive rate on RBEL exceedance.

KEY POINT: **JE model does not provide reliable screening of potential indoor vapor impacts for this database.**

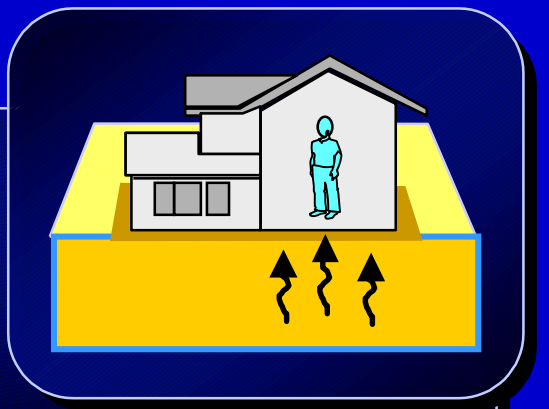
Screening Criteria for Indoor Air Pathway

Site Database:
Classification by Vapor Exposure Level

Potential Vapor Exposure Level		
	< RBEL	C_m < Greater of Background or RBEL
	> RBEL	Greater of Bkgrd or RBEL < C_m

APPLICABLE EXPOSURE LIMIT:

RBEL = Risk-Based Exposure Limit for residential air inhalation scenario with HQ = 1, TR = 10^{-6} or 10^{-5}.



C_m = Conc. of COC measured in indoor air; HQ = Hazard Quotient; ° RBEL = Risk-Based Exposure Limit; TR = Target Risk

Screening Criteria for Indoor Air Pathway

Vapor Site Database:
Classification by Indoor Vapor Level

	TOTAL NO.	MEASURED INDOOR VAPOR LEVEL					
		< RBEL (10^{-6})		> RBEL (10^{-6})		> RBEL (10^{-5})	
		No.	%	No.	%	No.	%
All Cases	**93**	**72**	**77%**	**21**	**23%**	**13**	**14%**
Fuel COCs	**67**	**59**	**88%**	**8**	**12%**	**4**	**6%**
■ BTEX	63	56	89%	7	11%	4	6%
■ MTBE	4	3	75%	1	25%	0	0
Solvent COCs	**26**	**13**	**50%**	**13**	**50%**	**9**	**35%**

KEY FINDING: **Most fuel sites (88%) are below 10^{-6} RBEL. Half of solvent sites are above.**

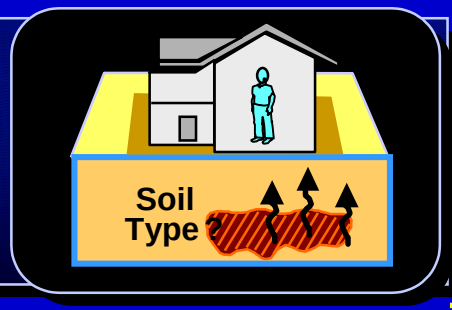
RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels: *Effect of Soil Type*

SOIL TYPE	TOTAL NO.	MEASURED INDOOR VAPOR LEVEL					
		< RBEL (10^{-6})		> RBEL (10^{-6})		> RBEL (10^{-5})	
		No.	%	No.	%	No.	%
Sand / Gravel	36	27	75%	9	25 %	6	17%
Sand	55	43	78%	12	22 %	7	13%
Silt / Clay	2	2	100%	0	0%	0	0%

KEY FINDING: **Most sites in database have sand or gravel soils. Silt/clay sites measured show no exposure > 10^{-6} RBEL.**



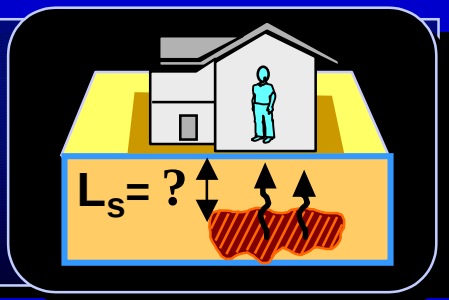
RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels: *Effect of Depth to Source*

Depth to Source Below Foundation	TOTAL NO.	MEASURED INDOOR VAPOR LEVEL					
		< RBEL (10^{-6})		> RBEL (10^{-6})		> RBEL (10^{-5})	
		No.	%	No.	%	No.	%
< 5 ft	13	8	62 %	5	38 %	3	23 %
5 - 10 ft	60	44	73 %	16	27 %	10	17 %
> 10 ft	20	20	100 %	0	0 %	0	0 %

KEY FINDING: **For source depths > 10 ft, indoor vapor levels are less than 10^{-6} RBEL for all compounds and all soil types in database.**



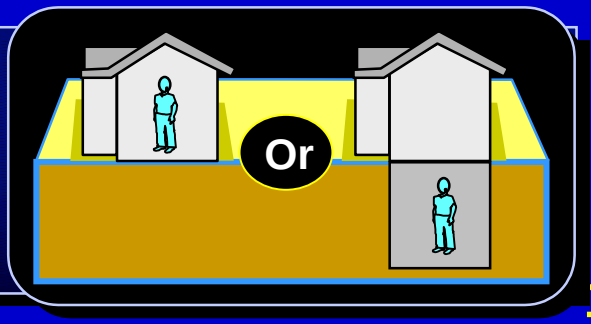
RBEL = Risk-Based Exposure Limit; Depth to Source = Distance below foundation to affected soil or groundwater source.

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels: *Effect of Foundation Type*

Foundation Type	TOTAL NO.	MEASURED INDOOR VAPOR LEVEL					
		< RBEL (10^{-6})		> RBEL (10^{-6})		> RBEL (10^{-5})	
		No.	%	No.	%	No.	%
No/Partial Foundation	5	2	40 %	3	60 %	1	20 %
Concrete w/ Basement	48	42	88 %	6	13 %	4	8%
Concrete, No Basement	30	20	67 %	10	33 %	6	20 %

KEY FINDING: **Higher impacts associated with bare soil, but no additional risk observed with basement.**



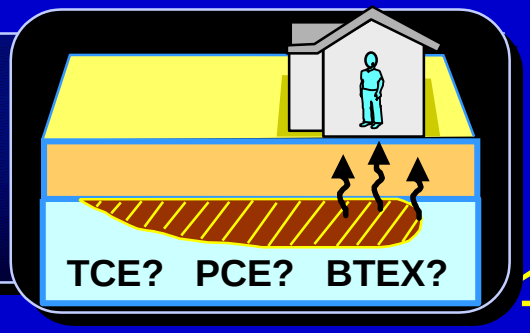
RBEL = Risk-Based Exposure Limit;

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels:
Effect of COC Concentration in GW (Cgw)

Conc. in GW (C_{gw})	TOTAL NO.	MEASURED INDOOR VAPOR LEVEL			
		< RBEL (10^{-6})		> RBEL (10^{-6})	
		No.	%	No.	%
$C_{gw} \leq 0.5$ mg/L	28	24	86 %	4	14 %
$0.5 < C_{gw} \leq 1$ mg/L	13	9	69 %	4	31 %
$1 < C_{gw} \leq 5$ mg/L	27	21	78 %	6	22 %
$C_{gw} > 5$ mg/L	17	12	71 %	5	29 %

KEY FINDING: No significant correlation of vapor impact with C_{gw} for either fuels or solvents.



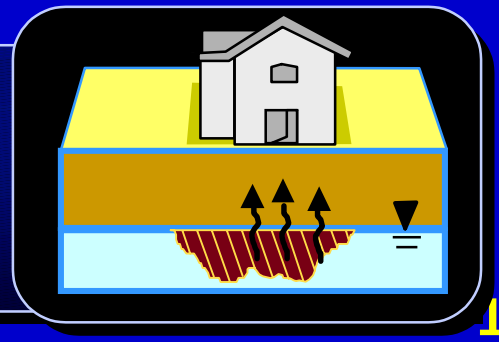
GW = Groundwater; RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels: *Effect of NAPL*

NAPL Condition	MEASURED INDOOR VAPOR LEVEL						
	TOTAL NO.	< RBEL (10^{-6})		> RBEL (10^{-6})		> RBEL (10^{-5})	
		No.	%	No.	%	No.	%
NAPL, Any Depth	10	8	80 %	2	20 %	1	10 %
NAPL, L_s > 10 ft	4	4	100 %	0	0 %	0	0 %
GW Seepage into Basement	3	1	33 %	2	67 %	1	33 %

KEY FINDING: **NAPL not generally indicative of vapor problem and never if depth > 10 ft. Direct GW seepage = bad news.**



RBEL = Risk-Based Exposure Limit; NAPL = Non-aqueous phase liquid

Screening Criteria for Indoor Air Pathway

Measured Vapor Levels: *Key Screening Criteria*

No Exceedance of Indoor Air Risk Limit (10^{-6})

If:

Empirical Screening Criterion	No. Cases	No. > RBEL (10^{-6})
■ Depth to Source > 10 ft, any COC, any soil, any concentration.	20	0
■ Fuel COC, L_s > 6 ft, concentration < 1 mg/L	17	0

KEY FINDING:

For this site database, simple criteria can identify no-risk cases.

Rules of Thumb

L_s = Depth to source below foundation.

Screening Criteria for Indoor Air Pathway

J-E Model vs. Empirical Screening Criteria

		J-E Model: Diffusion-Only Mode	
Site Condition	TOTAL No.	10^{-6} RBEL	10^{-5} RBEL
1 *L_s > 10 ft, All COCs*	20	FP: 2 % FN: 0 %	FP: 15% FN: 5%
2 *Fuels, L_s > 6 ft, COC < 1 mg/L in GW*	18	FP: 0 % FN: 0 %	FP: 0 % FN: 0 %

KEY FINDING: **Diffusion-only model overpredicts vapor impacts from deep sources (> 10 ft) but OK with "fuel rule."**

COCs = Constituents of Concern; FP = False Positive; FN = False Negative; RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

J-E Model vs. Empirical Screening Criteria

		J-E Model: Diffusion / Advection Mode	
Site Condition	TOTAL No.	10^{-6} RBEL	10^{-5} RBEL
1 *L_s > 10 ft*	20	FP: 50 % FN: 0 %	FP: 45 % FN: 0 %
2 *Fuels, L_s > 6 ft, COC < 1 mg/L in GW*	18	FP: 11 % FN: 0 %	FP: 11 % FN: 0 %

KEY FINDING: **Advection-mode model more significantly overpredicts vapor impacts from deep sources (> 10 ft), moderately overpredicts for "fuel rule."**

FP = False Positive; FN = False Negative; RBEL = Risk-Based Exposure Limit

Screening Criteria for Indoor Air Pathway

Recommended Approach

Empirical Screening Criteria	■ **Soil Type, Depth, Etc.:** Always use as first step in pathway screening process.
Screening Model (Optional)	■ ***JE, Others:*** Use improved model as optional screening tool to eliminate sites from further evaluation.
Site Measurements	■ ***Indoor Air or Soil Vapors:*** When appropriate, conduct soil vapor or direct indoor air sampling but must correct for other sources, background levels, etc.

Screening Criteria for Indoor Air Pathway

Further Work Needed

- ***Additional Site Data:***
  Compile more data, for all soil types, to confirm / refine screening criteria.
- ***Sampling Guidelines:***
  Identify reliable methods for measurement and interpretation of vapor levels in subsurface and indoors.
- ***Transient Effects and Biodegradation:***
  Characterize effect of soil type & other site-specific factors on vapor transport times & biodegradation rates.